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Hydrothermal fluid evolution and ore genesis in the Arghash epithermal gold prospect, northeastern Iran

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ABSTRACT

The Arghash epithermal gold prospect is located in the Sabzevar zone near the northern margin of the Central Iranian Microcontinent. The prospect includes six gold vein systems, hosted mostly by Lower-Middle Eocene intermediate to felsic volcanic and intrusive rocks with chemical compositions characteristic of continental arc magmas. Wall rocks are variably altered to clay minerals and subordinate carbonates, chlorite, and epidote, with intense alteration confined within 1–5 m of the veins. Mineralization consists of fracture fillings with local occurrences of hydrothermal breccias, and disseminations and veinlets in the immediate wall rocks. The veins consist of quartz, carbonates, minor sulfides, and gold. Pyrite is the main sulfide mineral in the hypogene ore in all vein systems except Au-VI where abundant stibnite occurs intergrown with quartz and minor pyrite; base metal sulfides are rare. Four generations of pyrite were identified: (1) disseminated euhedral to anhedral pyrite (Py-I), with up to 430 ppm Au; (2) framboidal pyrite (Py-II) with concentric As-poor and As-rich bands and up to 960 ppm Au; (3) arsenian pyrite overgrowths (Py-III) occurring on euhedral to anhedral Py-I grains, with up to 1980 ppm Au; and (4) fracture-filling, late-stage pyrite (Py-IV) that is anhedral and barren.

Homogenization and ice-melting temperatures of fluid inclusions vary from 186 to 306 °C and −0.1 to −3.2 °C in quartz, and from 169 to 287 °C and 0.0 to 2.3 °C in calcite, respectively. Laser combustion analyses indicate a narrow range of $\delta^{34}S$ values for Pyrites I–III, between −5.8‰ and +0.1‰, consistent with a magmatic source for sulfur. Pyrite IV is highly enriched in ^{34}S ($\delta^{34}S$ = +8.9‰ to +23.7‰), and may reflect a contribution from a source enriched in ^{34}S, such as evaporites. The $\delta^{34}S$ values for two stibnite samples from the stibnite-rich vein (−18.8‰ and −14.4‰) sharply contrast with those of the pyrite, suggesting a different sulfur, and possibly metal source, or strong fractionation. The $\delta^{13}C$ values for calcite are near 1‰, which is typical of marine carbonates. The calculated $\delta^{18}O$ values for the hydrothermal fluid in equilibrium with quartz range from +5.5‰ to +7.1‰, and the calculated δD values of the fluid in equilibrium with illite range from −48‰ to −57‰.

The fluid inclusion and stable isotope data suggest that the fluids experienced a complex history of prolonged water/rock interaction, boiling, and mixing. Evidence for boiling is shown by quartz pseudomorphs after bladed calcite and coexisting vapor-rich and liquid-rich fluid inclusions. Water/rock interaction is supported by the occurrence of sulfides and anomalous concentrations of gold in the altered wall rocks adjacent to veins. The alteration and ore mineralogy, textures, fluid inclusion data, and calculated fluid isotopic composition are more consistent with the described characteristics of low-sulfidation epithermal deposits.

1. Introduction

Numerous epithermal precious and base metal prospects and occurrences, some with historic mining records, occur in Iran, mostly associated with three Tertiary magmatic belts known as Urumieh-Dokhtar, Alborz, and Central Iran (Fig. 1). The Arghash gold prospect of Central Iran was discovered in 1994 through a systematic stream sediment-sampling program in which anomalies of Au, Ag, As, Sb, and Hg were found (Geological Survey of Iran, 1995). The prospect consists of six gold vein systems. The resource for two of the larger vein systems has been estimated, based on 32 drill holes, 50–160 m deep, and numerous trenches, to be approximately 2 million metric tons (Mt) with an average grade of 1.9 g/t Au (Geological Survey of Iran, 2001). The objective of this study is to evaluate the nature of the host rocks, the source, and evolution of the hydrothermal fluids, and the processes controlling ore deposition.

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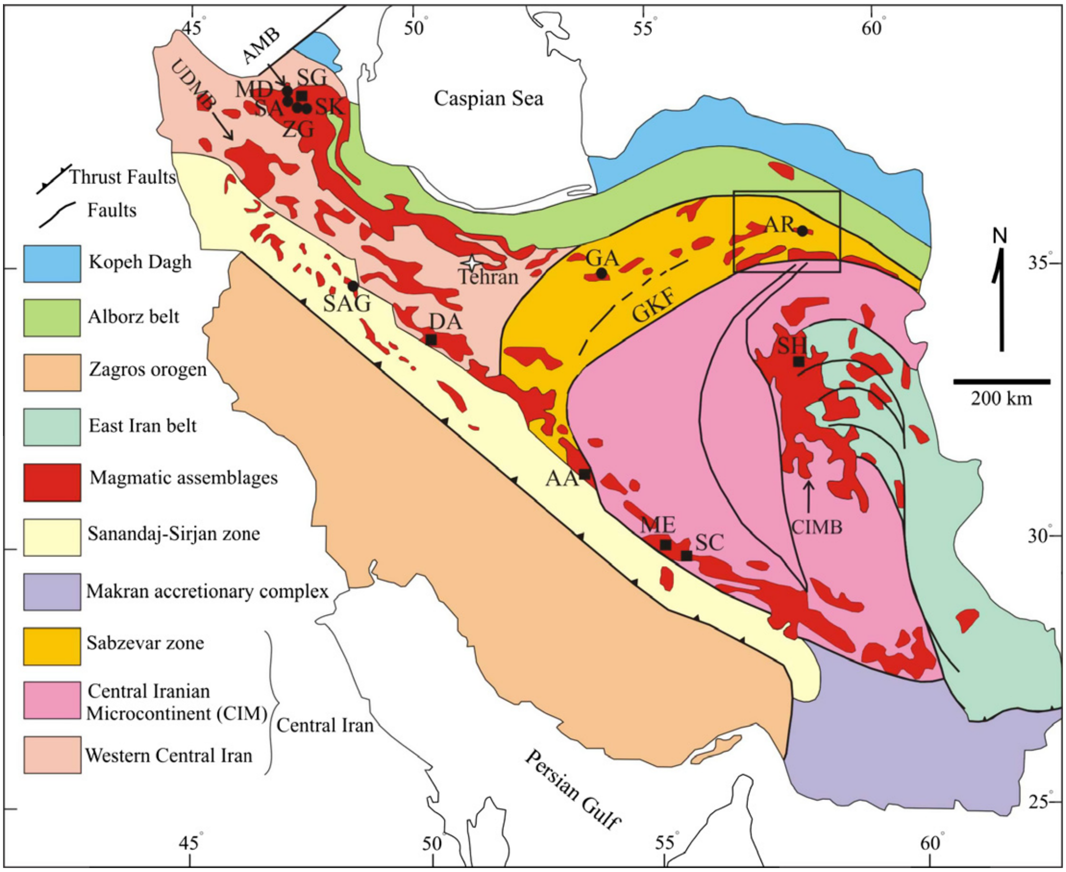

Fig. 1. Simplified structural map of Iran (compiled from Stöcklin, 1968; Alavi, 1996). Paleogene magmatism is the most voluminous magmatic episode in Iran and includes the Urumieh-Dokhtar magmatic belt (UDMB), the Alborz magmatic belt (AMB), and the Central Iran magmatic belt (CIMB). The Sabzevar zone, the Central Iranian Microcontinent (CIM), and the western Central Iran are collectively known as Central Iran. The box shows the location of Fig. 2. GKF: Great Kavir Fault. Epithermal Au: MD-Masjed Daghi; SA-Sharafabad; ZG-Zaglic; SK-Safikhanlou; SAG-Sari Gunay; GA-Gandi and Abolhassani; AR-Arghash. Porphyry Cu ± Mo ± Au: SG-Sungun; DA-Dali; AA-Aliabad; SC-Sarcheshmeh; ME-Meiduk; SH-Shadan.

2. Regional geology

The Arghash gold prospect is located in the eastern segment of the Sabzevar zone, north of the Central Iranian Microcontinent (CIM) (Fig. 1). The basement of the Sabzevar zone consists of metamorphosed rocks of Precambrian age covered by Paleozoic epicontinental sedimentary rocks. From the Late Triassic to the Cretaceous, rifting between the CIM and the southern margin of the Eurasia plate resulted in the formation of a narrow branch of Neo-Tethys II (Glennie, 2000), known as the Sabzevar Ocean (Sengör, 1990). The Sabzevar Ocean began to close in the late Cretaceous as a result of northward-directed subduction under northeast Central Iran and the eastern Alborz belt (Stöcklin, 1968) and was ultimately destroyed in the Miocene (Glennie, 2000; McQuarrie et al., 2003). This subduction was associated with the development of a magmatic arc in northeastern Iran. The Neo-Tethys ocean extended through Iran, although its evolution and the relationship of related arcs to mineralization typical of convergent plate margins is, at present, poorly constrained (e.g., Richards et al., 2006 and references therein). Remnants of the Sabzevar Ocean are preserved as fragments of ophiolite mélange (Fig. 2), consisting of highly dismembered serpentinized peridotites, gabbros, sheeted dikes, massive and pillow basalts, podiform chromite, and subordinate felsic-intermediate volcanic rocks, and pelagic sedimentary rocks (Spies et al., 1983).

The post-ophiolitic rocks in northeast Sabzevar consist of a thick sequence of Tertiary andesitic and dacitic lavas, tuffs, agglomerates, and minor limestone, sandstone, and evaporite beds (Emami et al., 1993). The volcanic rocks are intruded by felsic-intermediate intrusions in the Arghash district and to the south.

3. Geology of the Arghash gold prospect

The Arghash gold prospect is underlain mostly by Tertiary volcanic, plutonic, and sedimentary rocks, and Late Cretaceous ophiolitic rocks. The ophiolites form small outcrops and consist of gabbros, silicified limestone, slate, spilitic pillow lavas and variably altered felsic-intermediate volcanic rocks (Fig. 3). Tertiary volcanic activity started in the Early to Middle Eocene with eruption of andesitic, trachyandesitic, basaltic andesite, and rhyodacitic lavas, associated with subordinate volcanic breccias, agglomerates, nummulitic limestone and conglomerate (Keivanfar and Asgari, 2000) (Fig. 3). The volcanic rocks are overlain by Middle Eocene sedimentary and volcanic rocks consisting of spilitic lavas, altered andesites, tuffs, sandy tuffs, and intercalations of sandstones and nummulitic limestones. The volcanic activity continued into the Late Eocene with deposition of tuffs, sandy tuffs, agglomerates, and andesitic and dacitic lavas followed by eruption of lavas and pyroclastic materials of trachyandesite, quartz-trachyandesite, and andesite composition.

Granite, granodiorite, diorite, and gabbro bodies intruded into the volcanic rocks in the northern and southern parts of the prospect. A pre-Oligocene age is proposed for the intrusive rocks based on crosscutting relations and the fact that fragments of these intrusions occur in the Late Oligocene–Miocene polymictic